DARPA Meta-Materials

Workshop

September 29, 2000

Greenbelt, MD

WIRELESS POWER TRANSMISSION RECTENNAS

Breakthrough Technologies Required

- **Controlled Surface Impedances**
  - **Materials that conform to non-flat surfaces but maintain specified electrical performance I.e., dielectric constant, loss factors**
- **Basic Diode Development & Evolution**
  - **Long-term development in fabrication and micro-device technologies such as GaAs and GaNitride**
  - **Power and efficiency**
    - **Watts/device**
    - **>85% efficiencies**
- **Monothlic fabrication of Embedded “systems on a chip”**
  - **Silicon carbide-based**
  - **Integral rectenna arrays and transmitting arrays**
  - **Require self-biasing networks**
  - **Power Relaying opportunities**
    - **Limited relaying**
    - **Basic modulation of power wave for comm/signaling**

Other Collaborations and Opportunities

- Teamed with ESLI, San Diego
  - Proposal in development for the Gossamer NRA
    - Microtruss for lightweight airborne/spaceborne power receiver applications
  - Integrating rectennas with carbon fiber
  - CETDP "Lightweight Deployable Lens Antenna"
    - Ultralight "Microtruss Composite" material
    - Compressibility and resilience for storage and unfurling
- Other Teaming
  - Microwave Sciences/ESLI
    - RF Sail for Advanced Propulsion
  - NASA Langley
    - Rectennas for actuator applications
    - Conformable I.e., "smart skins"

Magnetoelectric Materials

<u>Magnetoelectric Medium</u> is a medium in which there exist a linear relationship between an electric field and the medium's magnetic polarization and between a magnetic field and the medium's electric polarization. :

$$\mathbf{D}(\omega) = \varepsilon_0\, \mathbf{E}(\omega) + \mathbf{P}(\omega) = \varepsilon_0\, \mathbf{E}(\omega) + \chi_{(e)} \bullet \mathbf{E}(\omega) + \chi_{(em)} \bullet \mathbf{B}(\omega)$$

$$\mathbf{H}(\omega) = \mu_0^{-1}\, \mathbf{B}(\omega) - \mathbf{M}(\omega) = \mu_0^{-1}\, \mathbf{B}(\omega) - \chi_{(m)} \bullet \mathbf{B}(\omega) - \chi_{(me)} \bullet \mathbf{E}(\omega)$$

Where, ε_0 and μ_0 are the permittivity and the permeability of free space

$\mathbf{D}(\omega)$ and $\mathbf{H}(\omega)$ are components of the electromagnetic induction field phasor

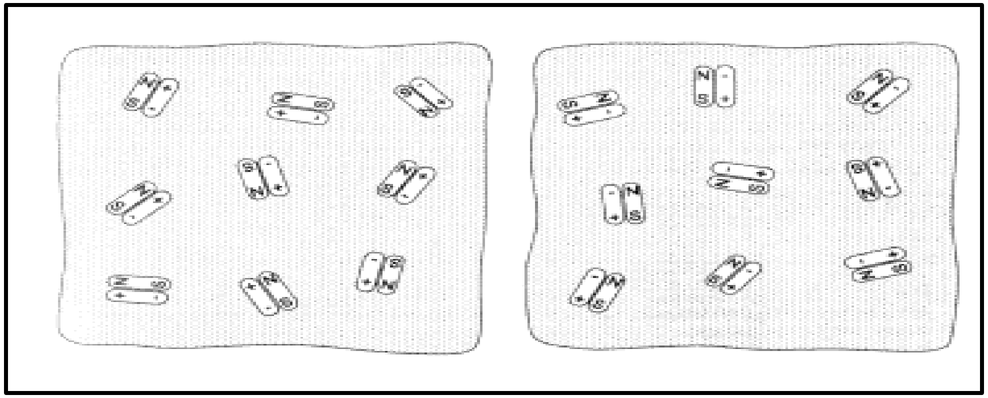
$\mathbf{E}(\omega)$ and $\mathbf{B}(\omega)$ are components of the electromagnetic primitive field phasor.

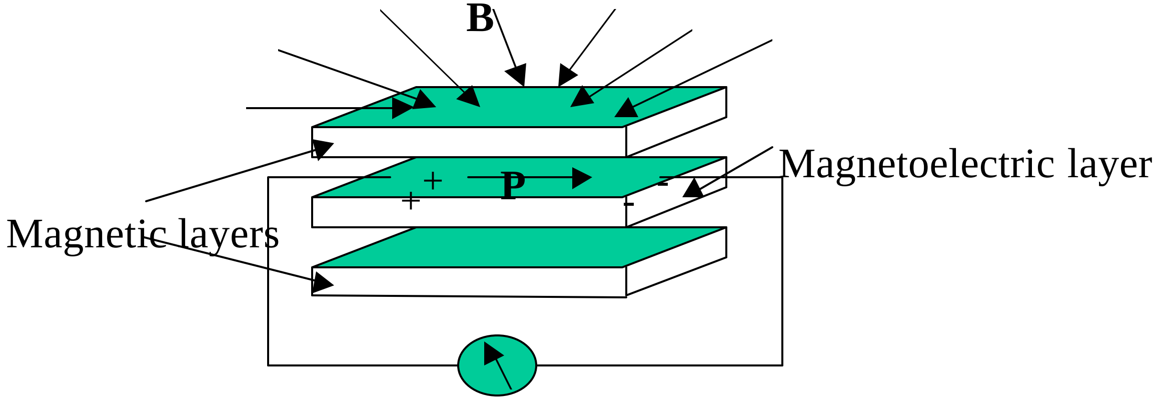
$\mathbf{P}(\omega)$ and $\mathbf{M}(\omega)$ are the polarization magnetization phasors.

$\underline{\chi}_{(e)}$ and $\underline{\chi}_{(m)}$ are the electric and magnetic susceptibility tensors.

$\underline{\chi}_{(me)}$ and $\underline{\chi}_{(em)}$ are the **magnetoelectric** and the **electromagnetic** susceptibility tensors.

Magnetoelectric Materials





Magnetoelectric Materials

- Design and Development of Materials
  - Theory of Magnetoelectric (ME) effect
  - Fabrication of thin-film materials
  - Testing (cryogenically as well as R.T.)

- Integration to Monolithic Fabrication Processes
  - Processing and ME materials compatibility
  - Processing, thickness examination w.r.t. ME susceptibility tensor orientation
  - Theory examination

- Develop Proof-of-concept Device and Application
  - Device modeling and simulation for Long-term device fabrication
  - Power (sensing) and efficiency
    - (1-5) Watts/device
    - <2.0 volt/60,000nT